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From Uranium Enrichment to Renewable Energy: Conversion of the US-DOE's Former Portsmouth Gaseous Diffusion Plant (PORTS) in Piketon, Ohio, into a Clean Energy Production Facility Within a Decade

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A WHITE PAPER

FROM URANIUM ENRICHMENT TO RENEWABLE ENERGY:

CONVERSION OF THE US-DOE's FORMER PORTSMOUTH GASEOUS DIFFUSION PLANT (PORTS) IN PIKETON, OHIO, INTO A CLEAN ENERGY PRODUCTION FACILITY WITHIN A DECADE

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Ohio University - May 2014

Abstract

The large-scale energy production projects described here, of which the Portsmouth Solar Power Production site at Piketon Ohio is the illustrative example, are chosen to describe how multi-megawatt quantities of “baseload” renewable electrical power can be reliably generated from terrestrial solar farms. Also to be shown are the steps to be taken in making these energy resources simultaneously available to local and global power grids, 24-hours-a-day 12-months-a-year.

This paper focuses attention on The U.S. Department Of Energy’s former Portsmouth Gaseous Diffusion Plant (PORTS), a Cold War-era uranium enrichment plant located on a secure 3,700+ acres in a rural area of SE Ohio. The authors argue that the PORTS plant is a suitable demonstration site for the first-ever fully integrated ground solar and space solar energy production facility. In the scenario outlined below, the former gaseous diffusion facility in Ohio will be repurposed as a utility-scale producer of clean and renewable electrical power, approximating the quantities of electricity it consumed after 1955, when two coal-fired plants were installed on the Ohio River to feed it.

As proposed, conversion of the plant to renewable energy production will take place in three stages: by 2018, a stand-alone terrestrial (PV) solar farm will be installed on an estimated 600 acres; by 2020, reflected sunlight will be beamed to the site from space mirrors placed in medium-to-low earth space orbits for the purpose of enhancing the intensity of solar radiation at the site and extending the solar day by four hours in the morning and four hours in the evening; and by 2022, sun power converted to electromagnetic energy in the form of continuous wireless microwave transmissions originating in a high geosynchronous space orbit will be targeting a raised mesh antenna installed directly over the solar farm. This will be a rectifying antenna (rectenna) serving as the ground receiver and converter for the energy beams of the GSO positioned satellite mated to it, while allowing the sunlight to fall through to the photovoltaic panels directly below it.

Sun’s energy acquired via these PV and microwave platforms will be translated into alternating (AC) current flowing continuously outward into the local community via the same high voltage electrical grid that once powered uranium

enrichment processing at the Portsmouth site. Further, the authors illustrate several ways the mating of space solar and terrestrial solar installations for renewable power production can be repeated in other locations around the globe.

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Attached below is a screen shot of the Ports location lifted from a 3D animation of the site produced by the Ohio University Game Research in Immersive Design (GRID) Lab for the Voinovich School of Leadership and Public Affairs under a U.S. Department of Energy grant. A 5-Minute Social Media Visualization of the site being converted into a facility for clean energy production (and related businesses) has been created by students and staff of the GRID Lab using this White Paper as a guide. This paper and visualization were presented (and given further critique) at the International Space Development Conference in Los Angeles in May 2014.

The Proposal: This paper advances the proposition that “the most-promising-of-all-future-scenarios for the former Portsmouth Gaseous Diffusion Plant in SE Ohio (and numerous other such sites around the world) is as a repurposed facility for electrical power production.” The authors will explain in their proposal how the Cold War-era uranium enrichment facility can now be transformed into a high-capacity supplier of clean and renewable energy within a decade.

Outlined are some of the basic technical, administrative and other steps that will be needed to transform that facility into a terrestrial solar farm, augmented by space solar power, capable of producing one-half or more of the electricity it once consumed without needing to rely on coal.[1] The power it will generate will be the highly valued "new and renewable (NRE) energy" that can be used both on-site and off. Based on our background research – and consultations with informed authorities – we have arrived at a plan we think makes environmental sense, and is scientifically credible, technically doable and economically compelling over the long term.

Background: Located in Piketon, Ohio, the uranium enrichment plant was established by the U.S. Atomic Energy Commission in the early 1950s as a government facility to support the nation's nuclear weapons program, and later to produce the enriched uranium used by commercial nuclear reactors.[2]

Following the break-up of the Soviet Union and the signing of nuclear non-proliferation treaties, the U.S. government's Piketon gaseous diffusion operation at Portsmouth was privatized, and in 2005 the facility was shut down. Portions of the site are currently leased to two private sector endeavors including the United States Enrichment Corporation (USEC), that operates a centrifuge demonstration project, and Babcock & Wilcox Conversion Services LLC (BWCS) whose operations focus on converting depleted uranium hexafuoride (DUF6) into a more benign form for sale, disposal and long-term storage.

There are still some problems in making the site available for commercial or other activity. When operational, the plant generated hazardous, radioactive, chemical and nonchemical wastes and some quantities of depleted uranium, hexafluoride (DUF6) and surplus uranium materials are still stored onsite. At several locations within the secured boundaries of the plant, some buildings, soil, ground water and surface water are contaminated and have not yet been restored.[3]

It should be noted that this is not the only site of its kind. A similar situation exists at the Gaseous Diffusion Plant in Paducah KY, where the U.S. Department of Energy was in 2013 seeking a "deactivation contractor."[4] Likewise, after five decades of nuclear weapons development and government-sponsored nuclear energy research at the Los Alamos National Laboratory in Los Alamos NM, cleanup and remediation is now underway.[5] Although never so prominent or as

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[1] At the time the plant was built, it was estimated that 1.8 GWatts of electricity would be required, consuming about 7.5 million tons of coal annually. W.F. Drumeller, "Railroad to an 'A' Plant," C&O Magazine, March 2009, p.11.

[2] "Handbook on the Portsmouth Area," Atomic Energy Commission, Portsmouth Ohio, July 1956, pp.24.

[3] "Portsmouth Gaseous Diffusion Plant," U.S. Department of Energy, www.pppo.energy.gov/portsmouth.html. August 15, 2013.

[4] "DOE Seeks Deactivation Contractor for Paducah Gaseous Diffusion Plant," Office of Environmental Management, www.energy.gov, August 9, 2013.

[5] "DOE Awards Task Order for Disposal of Los Alamos National Laboratory Waste," Office of Environmental Management, www.energy.gov, July 11, 2013.

potentially dangerous as the Chernobyl (1986) power plant in Ukraine and the Fukushima Daiichi (2011) power plant in Japan, these and numerous other nuclear (and military protected sites) are under consideration as candidates for conversion-to-public use.

Our team goal has been to frame a plausible scenario in which those large acreage sites are made productive once again as “utility scale” solar farms, hosting additional businesses when plausible, but constructed in such a way that they can safely coexist with the ongoing cleanup activities and legacy management activities at former DOE sites.

The Plan: In this case, our team has focused its attention on the PORTS facility in Piketon, Ohio, as an illustrative example of how such locations might be converted into ground solar/space solar power production plants at acceptable costs and environmental conditions in a reasonable timeframe.

In the instance of PORTS, offering a great number of usable acres, we are proposing that the facility be repurposed over time in three incremental steps:

- first, a large platform of photovoltaic (PV) arrays will be installed for the purpose of capturing and converting daylight sunshine into clean and renewable energy, e.g., as electrical power that can be used onsite and the excess fed into the local electrical grid;

- two years later, the solar day of the PV site will be extended – and its installed capacity made more efficient – with the focusing of sun’s rays into an innocuous beam of reflected sunlight from dawn to dusk using space satellites operating in sun-synchronous orbits; and after

- two years more, an elevated mesh antenna - that allows the sunlight to pass through - will be installed directly over the PV panels that will serve as the rectifying receiver (rectenna) capable of generating an additional quantity of electricity from the microwaved power beams arriving at the site from space 24-hours-a-day.

PV Farm: Our team is proposing that the U.S. Department of Energy, Environmental Protection Agency, State of Ohio, contractors and other stakeholders consider pursuing, as a possible future, “the use of this site as a renewable energy production facility” and to prioritize its conversion into an industrial-scale terrestrial solar farm that can be installed and made operational even as mandated site cleanup and protections continue.

The idea may not be as daunting as it seems. In November 2011, a large-scale solar installation was brought online at the Brookhaven National Laboratory in New York State, a public/private venture of the DOE, the National Lab, the Long

Island Power Authority, a private business (BP Solar) and the general public.[6]

The Long Island Solar Farm is an example of a commercial project built on federally administered public land, agreed-to as a template for ongoing photovoltaic (PV) solar research and a model for large-scale solar power development. Among the advantages perceived were: 1) the availability of a large track of unused land (that had been a "Superfund" cleanup site), 2) the Long Island Power Authority needed greater quantities of energy generated from renewable power sources, and 3) an existing substation was immediately next to the site, thus, eliminating the need for laying new transmission lines and extensive grid integration.

The Long Island facility, consisting of 200 acres of PV panels, is rated at 32 megawatt (MWatt) hours of renewable energy, sufficient to power approximately 4,500 homes. Its estimated annual average energy output was 44 gigawatt (GWatt) hours. At the time, it was considered to be the largest solar photovoltaic power plant in the Eastern United States. Its estimated lifespan is 40 years (until 2051). The employment workforce was about 200 FTE (jobs) during construction, dropping to 2 FTE thereafter.

Using that facility as a point of comparison, we can estimate that 600 Portsmouth acres of PV panels will produce 96 MWatts of renewable energy, sufficient to power 13,500 homes. The annual average output - of a facility capturing 6-8 hours of sunlight at a similar latitude - will be approximately 132 GWatts. Coming online in the year 2018, the useful lifespan of the Portsmouth solar production facility will extend to the year 2058. Some 600 construction jobs will be created, with a small operational staff remaining on duty. These projections do not include the proposed space-based increments of: 1) 4-8 hours of reflected sunlight and 2) around-the-clock wireless transmission of electromagnetic energy.

It should also be noted that in 2009 the DOE created its Energy Parks Initiative (EPI), to take a focused look at landfills, brownfields, greenfields and federal facilities as opportunities for renewable energy development. These EPIs were proposed specifically to foster partnering of federal agencies with local and state governments and private industries to drive innovation and accelerate PV solar development.[7]

One such EPI installation is the Stateline Solar Farm on the California/Nevada border to be built on federal lands controlled by the U.S. Department of Interior. When operational, this 300 MW solar farm would be equivalent in electricity production capability to a typical gas-fired power plant serving about 90,000

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[6] "The Long Island Solar Farm," U.S. Department of Energy, DOE/G0-102013-3914, May 2013, ii, www.energy.gov. Also see Anders, R.S. "The Long Island Solar Farm." DOE/G0-102013-3914, May 2013.

[7] Gilbertson, M.A. (April 23, 2009). "Energy Parks Initiative." U.S. Department of Energy. www.em.doe.gov

homes. This is a project of First Solar Development, Inc.[8]

PV Farm plus Reflected Sunlight: At the 2013 International Space Development Conference in San Diego, photovoltaic systems designer Lewis Fraas introduced a new approach to implementation of space solar power. His paper and presentation was called "Sunbeams from Space Mirrors Feeding Solar Farms on the Ground at Dusk and Dawn."[9]

Fraas' strategy is to place space satellites in a lower sun-synchronous orbit for the purpose of gathering and focusing sun's rays into a beam of reflected sunlight. The innovation in this idea is to extend the solar day of terrestrial solar farms, thereby increasing solar production capacity to 60 percent and reducing solar electricity costs to under 6 cents/kwh by delivering sunlight to a given location some 12-14 hours per day.

Fraas uses as an example the 100 MW concentrated solar power (CSP) field now installed in Abu Dhabi and a hypothetical GW-size solar farm installed within the contamination zone around the Fukushima nuclear power plant in Japan. To accommodate to the rapidly changing positions of non-geostationary satellites in lower earth orbits – and to make the economics work for space mirrors – his approach is to install a constellation of 18 evenly spaced mirror satellites in an orbit with a 30-degree latitude and longitude view of the earth turning underneath. A 30-degree longitude would represent 2 hours of dwell time over a given site for each satellite. A solar spot size on earth from a mirror at 1,000 Km above would be approximately 10 Km.

He argues that the placement of lightweight mirrors/reflectors in a dawn-dusk space orbit will be simpler, thereby cheaper and more efficient, than converting sun's energy to electricity in space and then beaming it as microwaves to the ground where it must be converted once again to electricity. But to allow the space system to operate with maximum efficiency, multiple earth ground stations (terrestrial solar farms) should be signed up to receive the additional sunlight. Thus, another opportunity arises for the first-time development of 1) a global solar grid in space in cooperation with the commercial satellite industry and 2) international cooperation and exchange of energy between and among power utilities.

PV Farm with Elevated Space Solar Rectenna: From the 1960s, space scientists and engineers have assumed that the continuous generation of power from outer space required a solar power satellite positioned in geosynchronous (GSO) orbit. That is, to work at highest efficiency, a collector, concentrator and re-transmitter of sun's energy must be orbiting 36,000 Km above earth in the

[8] First Solar, "Plan of Development," Stateline Solar Farm, Sept.3, 2010.
[9] Frass, L. M., D. Flournoy, & T. Rusi, "Sunbeams from Space Mirrors Feeding Solar Farms on the Ground at Dusk and Dawn," presentation to the International Space Development Conference, San Diego, May 24, 2013.

Clarke belt - a space orbit named for the science fiction writer Arthur C. Clarke who popularized it - where the satellite would remain as if fixed in an orbital location relative to a given position on earth.

The energy collected by the arrays of the solar power satellite (SPS) would be converted in space into direct current and used to power microwave generators, operating in an approved gigahertz frequency, for wirelessly transmitting the energy to earth using a highly directive antenna. On the ground, a large rectifying antenna would collect the microwaves and convert them into alternating current (AC electricity) suitable for further distribution via the terrestrial electrical power grid.[10]

The high GSO orbit has so much going for it that few space solar satellite designs have departed from this approach. Historically, and until today, a typical SPS configuration is a GSO orbiting satellite with a solar panel area of about 10 Km in size, and a space-to-earth transmitting antenna of about 2 Km in diameter. On the ground, a 4 Km receiving antenna is thought to be the size needed to yield the electrical power equivalent of a utility scale power station. Such an antenna should fit comfortably within the 15 Km area encompassed by the Ports facility, especially when installed directly above the PV solar field.

From the perspective of renewable energy production, the principal advantage of the added GSO configuration is the 24-hour availability of solar power, which best meets the requirements of the terrestrial power utilities; they much prefer an uninterrupted power supply.[11] In partnership with a space energy provider, having the capability to deliver continuous (baseload) electricity will also be a major step-up for current and future terrestrial solar farms. Such arrangements will give new and renewable (NRE) energy providers a way to extend their production hours, thereby taking maximum advantage of those installed investments. With 24-hour augmented production in all days and seasons of the year, many of the larger terrestrial solar farms will be in a position to operate as a competitive local utility.

Geoffrey Landis of the NASA Glenn Research Center, Cleveland, was among those advancing the idea in the 1990s that space solar and ground solar were complementary technologies. He wrote: “Low-cost ground solar power is a necessary precursor to space solar power: Space solar power requires low cost, high production and high efficiency solar arrays, and these technologies will make ground solar attractive for many markets. The ground solar power market, in turn, will serve to develop the technology and the high-volume production

[10] Flournoy, D.M. (2012). Solar Power Satellites. New York: Springer Science + Business Media, p.20.

[11] Mankins, J.C. et. al. (2011). Space Solar Power: The First International Assessment of Space Solar Power – Opportunities, Issues and Potential Pathways Forward. International Academy of Astronautics, pp.239-242.

readiness for space solar power."[12]

"Since ground solar is a necessary precursor to space solar power, an analysis of space solar power should consider how it interfaces with the ground-based solar infrastructure that will be developing on a faster scale than the space infrastructure." He suggested that one of the ways that this interface could be optimized would be to "integrate solar and microwave receivers on ground. This will allow the space solar power to use the pre-existing land that has already been amortized by ground solar power receivers, and tie in to power conditioning and distribution networks that are already in place."[13]

He also noted the obvious advantage that that solar power satellites will be able to beam to receivers where ground solar is unavailable. By "filling in" power when ground solar is unavailable, space solar power will serve as the complement to solar. "This requires an analysis of the match between solar availability, power demand, and power availability from space."

Portsmouth's Conversion Opportunity: In 2005, the PORTS Gaseous Diffusion Plant's operational status was transferred from "cold standby" to "cold shutdown," and in 2010 the facility was engaged in a process of deactivation, decommissioning and clean-up.

Residents of Pike, Scioto, Ross and Jackson counties in Ohio, many of them former employees, were surveyed about the Plant's future in 2012, resulting in multiple scenarios being suggested.[14] In order of preference, the top items were: Nuclear Power Plant, Green Energy Production, Industrial Park, National R&D Warehousing, Training and Education, Metal Recovery. Multi-use Southern Ohio Education Center, and Greenbelt. Most participants thought the facility could accommodate more than one of these options.

It is in the context of future planning for the site that our proposal is advanced for consideration. Portsmouth's features that make ground solar/space solar electricity production a particularly attractive option are:

- A rural location of more than 3,700 acres of government-owned and protected land that is connected by high voltage power lines to two coal-fired power plants on the Ohio River – 1GW Kyger Creek (1955) near Gallipolis OH and 1.3GW Clipty Creek (1956) near Madison IN.[15]

[12] Landis, G.A. "Reinventing the Solar Power Satellite." Glenn Research Center, Cleveland, Ohio, NASA/TM -2004-212743, p.10.
[13] Landis, G.A. p.11
[14] Morrone, M. et al. PORTSfuture Public Outreach Report. Voinovich School of Leadership and Public Affairs and Department of Social and Public Health of Ohio University, February 2012, pp. 501.

[15] Parker, Karen, "The C&O and the Portsmouth Gaseous Diffusion Plant," C&O: The Chesapeake and Ohio Historical Magazine, March 2009, 13 pp.

- At peek performance two double-circuit power lines were operating at 330 Kvolts; each circuit had 1MW capacity for power lines 50-75 miles long. These lines fed into switchyards, where large conduit networks delivered power across the site.
- The electrical switch is located in the NE quadrant of the site adjacent to the three large “process” buildings, each one-mile long, 550 feet wide and 80 feet tall.
- An on-site water treatment facility of 40-million gal/day capacity was available with access to the Scioto River and nearby well fields.
- Some 25 miles of road and 22 miles of railroad are installed around and within the plant.

Ground Solar Production Potential: To get an idea of how much electricity might be generated at Portsmouth, we asked Geoff Greenfield, founder of an Inc.500 company in Athens OH that designs and builds PV solar energy systems, to give us some of the most relevant metrics for our SE Ohio location.[16]

Starting with a single acre of PV collectors, Greenfield estimates that 1,036 panels rated at 260 watts each would allow for 269.36 KW of solar when performing at 14% efficiency. Projecting about a year ahead, budgetary pricing for this project would be about $2,000 per DC-rated KW total installed. So this solar farm acre would cost about $538,720.

When the panels are mounted in a fixed position on a stable, raised structure, an optimum year-around angle to capture the sun's rays would be 30 degrees. Greenfield noted that the DOE tool PVWatts can provide a monthly breakdown as well as a way of factoring all the various losses. He calculates that 269.36 KW production would generate 329,438 KWh/year of electricity.

Were this solar production facility to be upgraded in-place to 600 acres, the question was asked: “Would multiplying X 600 produce a reasonable estimate of equipment needed, efficiency, productivity, cost?” He replied, “Yes and no. Yes on the productivity side, since solar is modular and scalable. There would be some roads and non-solar space so he would use 90-95% of the 269.36 KW figure when the space goes above 5 acres. The costs should go down, however, with economies of scale.” He figured 600 Acres would allow for 161,616 KW (161 MW): “a system that large would be closer to $1,850 per KWDC.”

In answer to the question, “Are there other matters to be taken into consideration?” he responded: “Absolutely, any cost benefit or economic calculation needs to factor in the value of the tax credits (30%) as well as accelerated depreciation. Even if sited at a government facility like Portsmouth, these tax benefits can be partially monetized through a Power Purchase

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[16] Greenfield, G., President, Third Sun Solar, Athens, Ohio 45701, personal interview December 8, 2013.

Agreement." (Note: May 2014 legislation in Ohio has eliminated the tax incentive in question.) He did point out a second factor that affects the calculation: "annual degradation – industry standard is a conservative half a percent of energy output per year."

The Baseload Problem: Space economist John Strickland says storing power is ground solar's killer problem. He explains, "Where I live in 'sunny' Austin TX, we get 3 hours of full sunlight equivalent in the winter months. A city that uses 1 Gigawatt (1,000 Megawatts) of base load power needs that power for 24 hours a day. Thus it needs 24 Gigawatt-hours (24,000 Megawatt-hours) of baseload power every day." He notes that these calculations do not address the need for peak daytime power, which can sometimes be almost twice as much as baseload."[17]

"To generate that much power with ground solar in Austin in the winter, when you only have an average of 3 hours of equivalent full sun each day, you need to be generating enough power to use immediately, and also all the power needed for the other 21 hours when there is no effective sunshine. That means the collector needs to be at least 8 times larger, an 8 Gigawatt collector."

Strickland continues, "Estimates by a variety of sources indicate that ground solar and wind can supply about 20-30 percent of our US power needs before we run into the baseload barrier. This does not mean we should not use ground solar and wind. We just should not use it to supply baseload power. Both nuclear and space solar have the capacity to meet global energy needs and they require no storage."

An IAA Assessment of Space Solar Power appends a helpful "comparison of demand load vs ground renewable energy" that illustrates the general demand curve that might be expected in a middle state of the U.S. in summer.[18] The report notes that "a ground-based PV solar power system delivers power during daylight hours, and is highly dependent on the clarity of the air and the overall weather during the day." It also notes that "a wind farm delivers power based on the available wind conditions, and is highly dependent on the overall weather during any given day and/or season."

Integrated solar and wind power systems often fail to meet their maximum possible power output "because the intensity of the sunlight and the wind velocity peak at different times during the day." The current solution to meeting the demands of industrial societies for electrical power from renewable sources in

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[17] Strickland, J., a director of the National Space Society and the Space Power Association, personal correspondence, November 6, 2013.

[18] Mankins, J.C. et.al. (2011). Space solar Power: the First International Assessment of Space Solar Power – Opportunities, Issues and Potential Pathways Forward. International Academy of Astronautics, pp.239-242.

the local grid is "using hydroelectric power, nuclear power or (most typically) fossil fuel power plants to assure demand is met. In a future scenario involving stand-alone renewable energy sources, only large-scale energy storage systems will be capable of satisfying power demand requirements."

Ground Solar/Space Solar Sites Elsewhere: The authors are in the process of researching the locations of abandoned nuclear or military sites in other countries that might be brought online as terrestrial solar farms, with the potential to be interconnected via satellite. Our research question is: where are some of the plausibly suitable renewable energy production sites that would be in view of solar power satellites orbiting in a low-to-medium earth orbit?

For example, the location of PORTS and several other northern latitude sites make them well suited for the reception of energy wirelessly transmitted from space. The plant located at Piketon sits on a 3,700-acre federal reservation in rural Ohio at 39 degrees north latitude. By comparison, the companion Paducah KY plant occupies 750 acres on a 3,500 acre site in a more urban area at 36 degrees. The entire Los Alamos facility, including its University of California branch campus, is 23,600 acres at 35 degrees latitude. At the 36th parallel north latitude, for example, the sun is visible for 14 hours and 36 minutes during the summer solstice and 9 hours and 43 minutes during the winter solstice.

Using Piketon Ohio as a reference point at 39 degrees North latitude, looking East or West there may be a half-dozen prospective sites in North America. Crossing the Atlantic to Europe and Asia, there numerous others, which suggests there is a basis for establishing an international space energy consortium. Having multiple ground solar/space solar production facilities interconnected will greatly alter the economic proposition for new and renewable energy, and could make a big difference in meeting global carbon reduction goals.[19]

NRE Energy from Space: The generation of power directly from space is not a new idea. In our solar system, outer space is filled with intense sunlight, representing an inexhaustible supply of energy that can be converted to usable electricity either in space and on the ground. Just a small fraction of this energy will be sufficient to supply the greater part of the world's energy requirements, without the need for other fuel, and without producing any waste products. What is needed are large collectors/concentrators in space, and a way to transmit the power down to earth. Several different methods are possible, but the one that has received the most attention so far is wireless power transmission using microwave beams similar to those used in space-to-earth communication. Now, reflected sunlight using mirror satellites in space is also being given serious consideration.

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[19] Potter, S. et.al. "Space Solar Power Satellite Alternatives and Architectures: Analysis, Modeling, Simulation and Experimentation," The Boeing Company. AIAA Aerospace Sciences Meeting, Orlando FL, Jan. 5-8, 2009.

One of the merits of space solar power for terrestrial use is that it can help to address the “baseload storage” barrier facing ground solar and wind. In the replacement of carbon-based energy for baseload – which in most applications will represent up to 70% of the energy produced by local electrical utilities - ground solar and space solar can be complementary technologies, providing a permanent landing site for continuous wireless transmission of energy from space and eliminating most of the need for local storage.

NASA’s most recent Innovative Advance Concepts study has led to a very different architecture for solar power satellites operating from the higher GSO orbits. The new SPS-ALPHA design is proposed as “a hyper-modular approach” in which all platform elements can be mass-produced. This new architectural concept has led the researchers to predict “significantly lower development time and cost, much greater ease of manufacturing at lower cost, and significantly higher reliability.”[20]

The IAC Study Director John Mankins wrote, “If SPS-ALPHA can be developed, solar power in the range of 100s MW to 100s GW could be harvested in space and delivered efficiently to markets on earth, and to enable energy-rich operations throughout the inner solar system – transforming all aspects of government and commercial space.”

“Solar power satellites based on SPS-ALPHA could deliver power on demand to more than 90% of Earth’s population at locations across the globe. It would have a near zero “carbon footprint” and facilitate reaching greenhouse gas (GHG) emission reduction goals. Affordable and continuous solar energy delivered on large scale from SPS to the U.S. and other markets would transform terrestrial power since no other “green energy” technology has similar potential to provide (gigawatt quantities of) sustainable and ‘dispatchable’ baseload power that is essentially immune to diurnal variations or to weather.”

Space energy satellite designers from India, looking to use space mirrors in low earth orbit as a way to power desalination stations along its 3,000 miles of coastline, have hit upon a different solution to the baseload limitation. The innovation in this application is to “produce fresh water when the sun shines,” and store the water to be released whenever needed. For obvious reasons, they propose to move these units – both the PV fields and the SWRO equipment – off shore.[21]

The Space Solar Power Grid: Prof. Narayanan Komerath of the Georgia Institute of Technology has written extensively about the emerging international

[20] Mankins, J.C., “SPS-ALPHA: The First Practical Solar Power Satellite via Arbitrarily Large Phased Array,” (A 2011-2012 NASA NIAC Phase 1 Project), Final Report, September 15, 2012, p.105.

[21] Gopalaswami, R. “International Mission for Harvesting Energy from Space,” an unpublished paper, October 27, 2014.

interest in space solar power, largely as a result of rising energy costs and global warming concerns.[22] His students found that Japan's JAXA (Japan Aerospace Exploration Agency) had committed $21 billion towards the development of a 1GW solar power satellite, with plans for a Low Earth Orbit demonstration of wireless power beaming by 2015 and a functioning solar power satellite by 2040.[23] China has plans to complete a space solar power demonstration by 2025.[24] India has also expressed strong interest in non-fossil energy sources including both ground and space solar power.[25] [26]

The Georgia Tech team has been working on a key space architecture change that will allow power satellites to collect and transmit sun's energy from 2,000Km orbits rather than from a geosynchronous orbit at 36,000Km. This change, they argue, will greatly reduce the antenna sizes required, and also bring the spacecraft to a much more manageable size.[27] The plan would incorporate a constellation of relay satellites that would serve as a power exchange with terrestrial power entities, to include relaying power beamed from terrestrial power sites with excess power to high demand areas around the world.

This team has proposed a US-India space-based power exchange demonstration as a first step towards a space solar grid (SPG). They offer two options for approximating a 24-hour power exchange: 1) installation of four near-equatorial satellites at 5,500Km, with ground stations in USA, India, Australia and Egypt, or 2) alternative placement of six satellites in 5,500 Km orbits, with ground stations

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[22] Komerath, N. and P. Komerath, "Implications of Intersatellite Power Beaming Using a Space Power Grid," in IEEE Aerospace Conference, no. Paper P1696, Big Sky, MT, March 2011.

[23] Mori, M., H. Kagawa, and Y. Saito, "Summary of Studies on Space Solar Power Systems of Japan Aerospace Exploration Agency (Jaxa)," Acta Astronautica, vol. 59, no. 1, 2006.

[24] Flournoy, D., (2012). "How is Sunsat Development Faring Internationally?" Solar Power Satellites, New York: Springer Science and Business Media, pp. 67–78.

[25] [19] K. Chaudhary and B. Vishvakarma, "Feasibility study of Leo, Geo and Molniya Orbit Based Satellite Solar Power Station for Some Identified Sites in India," Advances in Space Research, vol. 46, no. 9, pp. 1177–1183, 2010.

[26] Gopalaswami, R. "Kalam-National Space Society Energy Technology Universal Initiative: An International Preliminary Feasibility Study on Space Based Solar Power Stations," Space Journal correspondence. October 2010.

[27] Dessanti, B. The Space Power Grid Approach to Space-based Solar Power: Special Problems Report, Experimental Aerodynamics and Concepts Group, Daniel Guggenheim School of Aerospace Engineering, Georgia Institute of Technology, Atlanta GA, December 2012.

only in the US and India.[28]

Potential Stakeholders/Investors: For many years, a common complaint among space scientists and engineers wanting to do research on space solar power has been that their proposals never get past the review panels in place. The reason is that SSP is perceived by NASA reviewers to be an "energy" project and by DOE it is considered to be a "space" project, thus not in either of their terms of reference.

Establishing a first-of-its-kind ground solar/space solar power production demonstration site at Portsmouth creates the opportunity for a unique global partnership between well-established and highly profitable commercial satellite industry players and those of the rapidly emerging terrestrial solar power industry.[29]

Seeing an entirely new category of business that will help in the repositioning of national economies, it is logical that DOE and NASA will each take some role in research support. But what will be more important locally, in the context of the PORTS Project, will be to engage the enterprise creation capacities of the State of Ohio, the regional utilities, the universities and technical colleges, and their local communities. Building an industrial scale electrical power production facility in SE Ohio – on a site that has been an environmental liability and drain on national and state resources for decades – is to create opportunities for investments in research, innovation and business that grow from the production of large quantities of new and renewable energy.

In examining the facilities and space available at the Portsmouth site, the authors have come to believe that businesses other than electrical power can be established there. In thinking about PORTS as an industrial park, where large quantities of clean and renewable electricity are produced on-site, this place could attract a cloud computing data center. The Apple server farm under construction in Maiden NC is a noteworthy example.

This North Carolina facility is thought to be five times larger than Apple's existing data center in Newark CA. It's purpose is not yet announced but it is presumed to be an additional location for housing and delivering digital music, video and other applications from the iTunes store.[30]

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[28] Komerath, N. et al., "A US-India Power Exchange Towards a Space Power Grid," A Georgia Institute of Technology, School of Aerospace Engineering, presentation made at the International Space Development Conference, Huntsville, AL May 2011.

[29] Flournoy, D. "Comsats and Sunsats: A Marriage Made in Heaven," a presentation given at Space Canada, the International Academy of Astronautics, IAA Study Group 3.11: Solar Energy From Space, Toronto, Canada, September 2009.

[30] Zeller, David. "Apple's Server Farm Hints at Cloud-based Ambitions," Money Morning, December 8, 2013, http://moneymorning.com/.

According to the author of the Apple article, “Other major tech companies, namely Microsoft Corp. and Google Inc., also have built their own data centers - both to curb reliance on external CDNs (content delivery networks) and to protect their cloud-based innovations from prying eyes.” Among the key criteria under consideration in attracting these types of businesses, is the offer of lots of room for expansion and abundant (and preferably clean and renewable) electrical power. Availability of fresh water may also be a positive factor.

In considering the space and facilities that exist on the Portsmouth site today, the authors have come to believe that an industrial park, where large quantities of electricity from renewable sources are produced on-site, will be especially attractive to companies with big data processing requirements.

In partnership with the communication satellite industry, capable of uplinking and downlinking streams of broadband data as well as NRE energy, the PORTS Production Project will be well positioned to become the first “multi-purpose demonstration node” in an international cloud consortium that will put this SE Ohio facility back on the map with a reputation for both clean energy production and fast data retrieval and distribution.

References:

Anthony, S. “Beam me down, Scotty: Space-based solar power finally comes of age,” February 28, 2013, http://www.extremetech.com/

Chapman, M. “GRID Lab Uses Animation to Translate ‘The Realm of the Possible’ in Solar Energy Capture,” Ohio University Compass, Feb.8, 2011.

Chaudhary K. and B. Vishvakarma, “Feasibility Study of LEO, GEO and Molniya Orbit Based Satellite Solar Power Station for Some Identified Sites in India,” Advances in Space Research, vol. 46, no. 9, 2010.

Dessanti, B. “The Space Power Grid Approach to Space-based Solar Power: Special Problems Report,” Experimental Aerodynamics and Concepts Group, Daniel Guggenheim School of Aerospace Engineering, Georgia Institute of Technology, Atlanta GA, December 2012.

“DOE Seeks Deactivation Contractor for Paducah Gaseous Diffusion Plant,” Office of Environmental Management, energy.gov, August 9, 2013.

“DOE Awards Task Order for Disposal of Los Alamos National Laboratory Waste,” Office of Environmental Management, U.S. energy.gov, July 11, 2013.

Drumeller, W.F. “Railroad to an ‘A’ Plant,” C&O Magazine, March 2009, p.11.

Flournoy, D. “Comsats and Sunsats: A Marriage Made in Heaven,” a presentation given at Space Canada, the International Academy of Astronautics, IAA Study Group 3.11: Solar Energy From Space, Toronto, Canada, September 2009.

Flournoy, D. "Solar Power Satellites: The Next Big Thing for the Satellite Industry" ORBITER, a publication of the Society of Satellite Professionals International, December 2009.

Flournoy, D. (2012). Solar Power Satellites, New York: Springer Science + Business Media, pp. 67–78.

Frass, L. M. (May 23, 2013). "Sunbeams from Space Mirrors Feeding Solar Farms on the Ground at Dusk and Dawn." The Online Journal of Space Communication, Issue No.17: Visualizing Space Polar Power. Spring 2013.

Glaser, P., "Method and Apparatus for Converting Solar Radiation to Electrical Power," (US Patent No. 3,781,647; U.S. Patent and Trademark Office; Washington, D.C.). December 25, 1973.

International Space Station, NASA Science, and Transportation, May 5, 2004. http://www1.eere.energy.gov/solar/pdfs/csp_sunshot_2011march_ramamoorthy.pdf

Gopalaswami, R. "Kalam-National Space Society Energy Technology Universal Initiative: An international preliminary feasibility study on space based solar power stations," Space Journal correspondence. October 2010.

Greenfield, G., President, Third Sun Solar, Athens, Ohio 45701, an interview, December 8, 2013.

"Handbook on the Portsmouth Area," Atomic Energy Commission, Portsmouth Ohio, July 1956, pp.24.

Komerath, N. et al., "A US-India Power Exchange Towards a Space Power Grid," A Georgia Institute of Technology, School of Aerospace Engineering, presentation made at the International Space Development Conference, Huntsville, AL May 2011.

Komerath, N. and P. Komerath, "Implications of Intersatellite Power Beaming Using a Space Power Grid," in IEEE Aerospace Conference, no. Paper P1696, Big Sky, MT, March 2011.

Landis, G.A. "An Evolutionary Path to SPS," Space Power, Vol. 9 No. 4, pp. 365–371 (1990).

Landis, G.A. "Reinventing the Solar Power Satellite." Glenn Research Center, Cleveland, Ohio, NASA/TM -2004-212743.

Mankins, J.C. et al. (2011). Space solar Power: the First International Assessment of Space Solar Power – Opportunities, Issues and Potential Pathways Forward. Paris: International Academy of Astronautics.

Mankins, J.C., “SPS-ALPHA: The First Practical Solar Power Satellite via Arbitrarily Large Phased Array,” (A 2011-2012 NASA NIAC Phase 1 Project), Final Report, September 15, 2012.

Morrone, M. et al. PORTSfuture Public Outreach Report. Voinovich School of Leadership and Public Affairs and Department of Social and Public Health of Ohio University, February 2012, pp. 501.

Mori, M., H. Kagawa, and Y. Saito, “Summary of Studies on Space Solar Power Systems of Japan Aerospace Exploration Agency (Jaxa),” Acta Astronautica, vol. 59, no. 1, 2006.

Musk, E., "Space Shuttle and the Future of Space Launch Vehicles," Senate Committee on Commerce, Science, and Transportation, May 5, 2004, http://www.lgarde.com/papers/2003-4659.pdf

Potter, S. et al. “Space Solar Power Satellite Alternatives and Architectures: Analysis, Modeling, Simulation and Experimentation,” The Boeing Company. AIAA Aerospace Sciences Meeting, Orlando FL, Jan. 5-8, 2009.

“Portsmouth Gaseous Diffusion Plant,” U.S. Department of Energy, www.pppo.energy.gov/portsmouth.html. August 15, 2013.

Strickland, J.K., a Director of the National Space Society and the Space Power Association, personal correspondence, November 6, 2013. Also see, Strickland, J.K., “Base Load Power from Earth and Space,” a presentation to the International Symposium on Solar Energy from Space, IAA “SPS Workshop, Toronto, Canada, September 2009

Zeller, David. “Apple’s Server Farm Hints at Cloud-based Ambitions,” Money Morning, December 8, 2013, http://moneymorning.com/.